INITIAL CONDITIONS (IC) BIAS CORRECTION METHOD FOR SEASONAL-TO-DECADAL CLIMATE PREDICTIONS

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ABSTRACT: Climate predictions initialized from observations (OBS) drift toward the state of an unconstrained model, which makes the use of post-processing correction methods critical to distinguish the climate signal of interest from the model error or bias. The mean (per-pair) bias correction method removes the mean bias at each forecast time from a climate forecast. However, the development of bias can also depend on the time of initialization. The trend bias correction method addresses this by replacing the linear regression of the model prediction on start dates for each forecast time with its OBS counterpart. Furthermore, certain variables exhibit nonlinear dependence of the drift on the initial date of the prediction because there is a critical dependence of the bias on the IC. We propose that applying a linear regression of the predictions and corresponding OBS on the OBS IC, and substituting the latter for the former, offers an effective method for bias correction that incorporates dependence on the state of internal variability and long-term forced response. The impact of this new IC bias correction method is examined on monthly means of the sea surface temperature and the Northern Hemisphere sea ice extent in EC-Earth2.3 climate predictions. Such post-processing adjustment through linear regression on the averaged OBS over the first forecast month as a temporarily smoothed proxy for OBS IC shows reduction of model errors with respect to the mean and trend bias correction methods. Improvements are shown for at least one season and for some variables up to 5 years.

REFERENCE: *Fučkar, N. S., D. Volpi, V. Guemas, and F. J. Doblas-Reyes (2014), A posteriori adjustment of near-term climate predictions: Accounting for the drift dependence on the initial conditions, Geophys. Res. Lett., 41, 5200–5207, doi:10.1002/2014GL060815.*

- Initializing dynamic climate predictions from observations induces a model drift

⇒ *How to best correct it?*

→ **We propose new method to account for the dependence of the drift on the initial state of prediction**

→ **Principle: linear regression of the model error at a given forecast time on IC (smoothed in time)**

The impact of new method is examined on monthly means of large-scale SST indices, and the Northern Hemisphere (NH) sea ice extent (SIE) in near-term climate predictions with EC-Earth2.3

- **Bias correction method I → MEAN BIAS CORRECTION METHOD**

$$m_{i,l} \equiv \overline{m_l} + m'_{i,l} \;\; and \;\; o_{i,l} \equiv \overline{o_l} + o'_{i,l},$$
$$m_{i,l} \longmapsto \hat{m}_{i,l} \equiv m_{i,l} - [\overline{m_l} - \overline{o_l}] = \overline{o_l} + m'_{i,l}.$$

- **Bias correction method II → TREND BIAS CORRECTION METHOD**

$$m_{i,l} \equiv [a_l^{(m)} + b_l^{(m)} i] + m''_{i,l} \;\; and \;\; o_{i,l} \equiv [a_l^{(o)} + b_l^{(o)} i] + o''_{i,l},$$
$$m_{i,l} \longmapsto \tilde{m}_{i,l} \equiv m_{i,l} - \{[a_l^{(m)} + b_l^{(m)} i] - [a_l^{(o)} + b_l^{(o)} i]\}$$
$$= \hat{m}_{i,l} - [b_l^{(m)} - b_l^{(o)}][i - \bar{i}].$$

m - "raw" forecast, o - obs/analysis, i – start date (year), l - forecast time

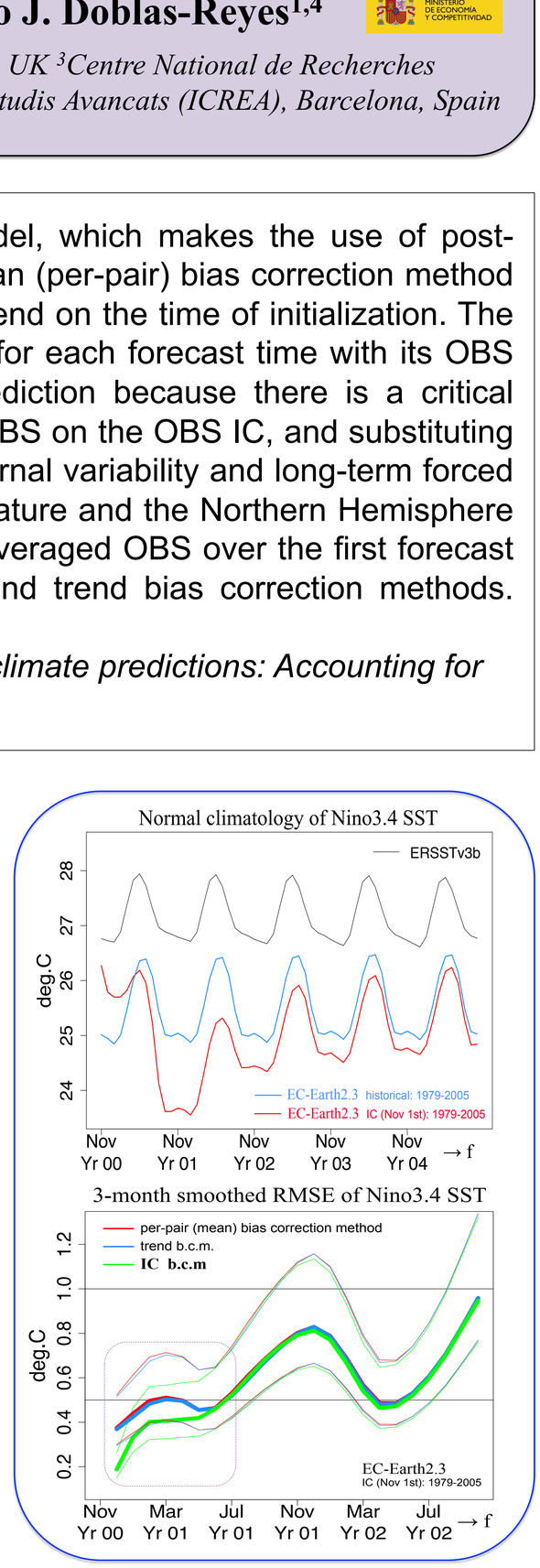
- **Bias correction method III → NEW IC BIAS CORRECTION METHOD**

$$m_{i,l} \equiv [\alpha_l^{(m)} + \beta_l^{(m)} o_i^{(IC)}] + m'''_{i,l} \;\; and \;\; o_{i,l} \equiv [\alpha_l^{(o)} + \beta_l^{(o)} o_i^{(IC)}] + o'''_{i,l},$$
$$m_{i,l} \longmapsto \tilde{\tilde{m}}_{i,l} \equiv m_{i,l} - \{[\alpha_l^{(m)} + \beta_l^{(m)} o_i^{(IC)}] - [\alpha_l^{(o)} + \beta_l^{(o)} o_i^{(IC)}]\}$$
$$= \hat{m}_{i,l} - [\beta_l^{(m)} - \beta_l^{(o)}][o_i^{(IC)} - \overline{o_i^{(IC)}}].$$

Instantaneous IC is too noisy ⇒ smoothing OBS IC in time is critical for monthly and longer-term predictions

Implemented: $o^{(IC)}_i = o_{i,1}$ (average over the first forecast month)

Other options: $o^{(IC)}_i = o_{i,-1}$, average from 15 days before to 15 days after IC, etc.

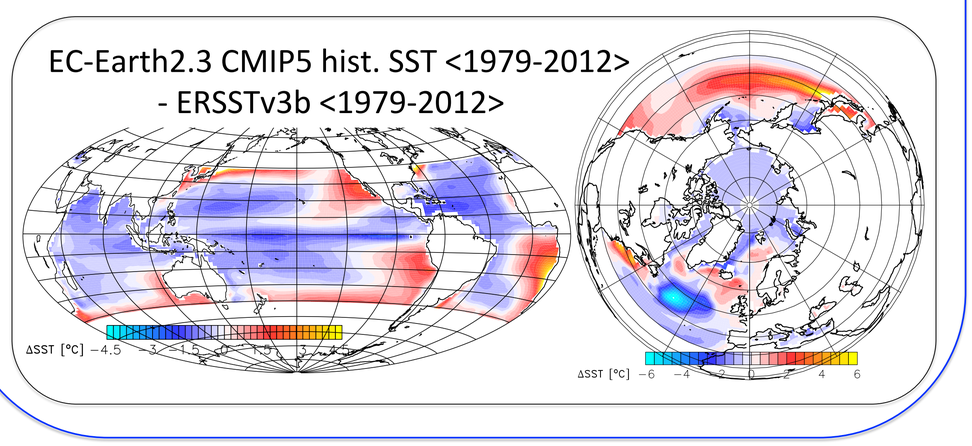


Coupled climate model EC-Earth2.3 (IFS + NEMO2/LIM2 + H-TESSEL)

- CMIP5 unconstrained historical simulation (using RCP4.5 forcing after 2005)
- CMIP5 5-member decadal predictions initialized on 1st of November from 1978 to 2005

Observations/analyses:

- NOAA ERSSTv3b monthly means
- NSIDC monthly sea ice extent (SIE) in the NH



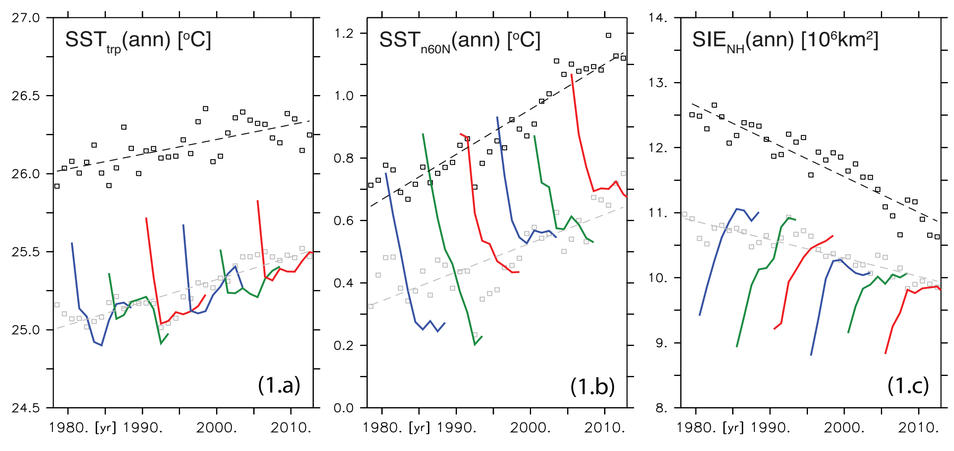
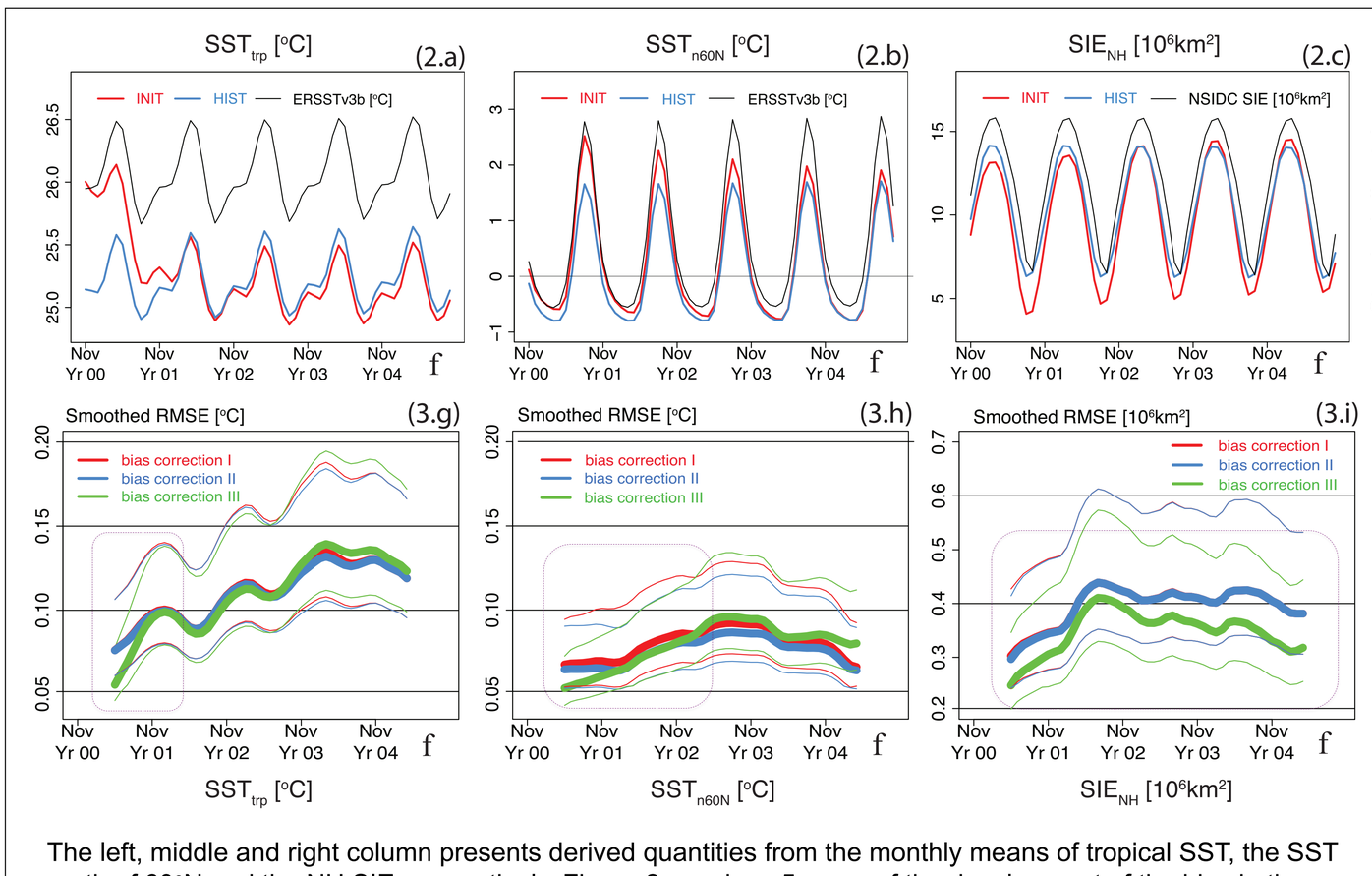


Figure 1.a-c Annual means of (a) tropical SST averaged between 30˚S and 30˚N, (b) SST averaged north of 60˚N, and (c) the NH SIE, from 1979 to 2012, for ERSSTv3b and NSIDC OBS (black squares), historical EC-Earth v2.3 simulations unconstrained by OBS (HIST - grey squares), and OBS initialized EC-Earth2.3 decadal predictions (INIT - colored curves show only every 5th).



The left, middle and right column presents derived quantities from the monthly means of tropical SST, the SST north of 60ºN and the NH SIE, respectively. Figure 2.a-c show 5 years of the development of the bias in the standard climatology for the initialized predictions (INIT- red curve) that in principle starts from the OBS (black curve) and converges to the historical simulation (HIST - blue curve). Figure 3.g-i show 12-month smoothed root mean square errors (RMSE) over 5-year forecast period for the mean bias correction adjustment (method I - red curve), the trend bias correction adjustment (method II - blue curve), and the new IC-based bias correction adjustment (method III - green curve). The thin curves mark the 95% confidence level based on χ^2 distribution.

→ **New IC bias correction method for climate predictions** that takes into account the conditional dependence of the drift on a smoothed proxy of observed IC through a **linear regression of the model error on observed conditions in the first forecast month** (instantaneous IC are too noisy)
→ **Improvements due to new IC method (over the mean and trend bias correction methods)** in deterministic skill of large-scale SST indices and the NH sea ice extent are shown from **at least the first forecast season up to five years**

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